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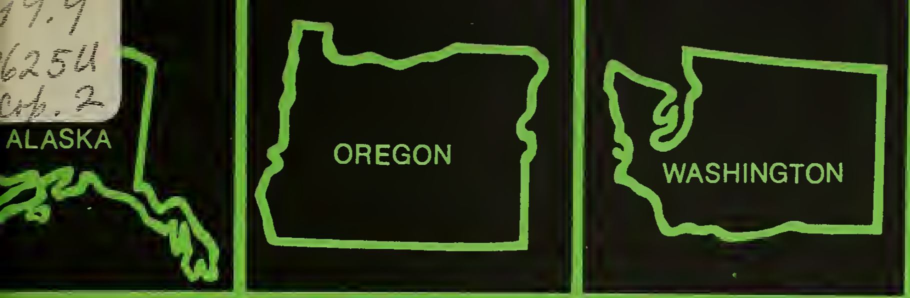

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· · USDA FOREST SERVICE RESEARCH NOTE

PNW-300

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FLOW RATES AND CHARACTERISTICS OF DIMILIN, DYLOX 1.5, ORTHENE 75S, AND SEVIN 4-OIL[1]

by

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Abstract

Flow rates are presented for Dimilin, Dylox 1.5, Orthene 75S, and Sevin 4-oil at five pressures and four temperatures using three standard T-jet nozzles. Physical properties of settling, density, and viscosity and handling characteristics are also discussed.

KEYWORDS: Insecticides, chemical control (-forest pests, Dimilin, Dylox, Orthene, Sevin.

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INTRODUCTION

In western North America the Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough), is a major pest of fir forests and can cause extensive tree mortality and growth loss.[3] One objective of the USDA Expanded Douglas-fir Tussock Moth Research and Development Program is to develop and test chemical insecticides capable of controlling the tussock moth and suitable for aerial application under mountainous forested conditions.[4] The most promising materials tested to date are Dimilin ®, Dylox 1.5 ®, Orthene 75S®, and Sevin 4-oil ®. The usual method of applying liquid chemicals against the tussock moth and other forest defoliators has been aerial application by helicopter or fixed-wing aircraft equipped with hydraulic spray nozzles and flat fan, T-jet nozzle tips (Spraying Systems Co., Wheaton, Ill.).

When such systems are used in the field, the number and size of the nozzle tips must be determined to produce the desired flow rate for a specific insecticide. The flow rate for a given type of nozzle, the number of nozzles used, and the speed of the aircraft determine the amount of material applied per acre. Unfortunately, we have no simple standard method of establishing the flow rate of nozzle tips for a new insecticide. Each material has a distinctive flow rate which changes with the boom pressure, the amount of diluent added to the material, and sometimes with the temperature. Knowing the flow rate of each material is, therefore, of major importance in planning and conducting a control program. This information is usually determined for each aircraft at the time of the program and is a time consuming, difficult, and, under field conditions, often an inexact procedure.

Standardized equipment was used under laboratory conditions to evaluate each of the four candidate materials to determine flow rate (volume per minute) through a series of flat fan nozzle tips at a range of temperatures, pressures, and dilutions likely to be encountered in the field under standard operating conditions. We planned to present the results of these tests, along with general observations of mixing and handling properties of the four materials, in a series of figures. A pilot, knowing the speed of his aircraft and the volume of materials to be delivered per acre, refers to these figures to determine the flow rate for each material for a given size nozzle, and determines the number of nozzles, the boom pressure, and nozzle size necessary to meet his application rates.

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[3] Wickman, Boyd E., Galen C. Trostle, and Paul E. Buffam. 1973. Douglas-fir tussock moth. USDA For. Serv. For. Pest Leafl. 86 (rev.), 6 p., illus.

[4] This paper reports work involving chemical insecticides. It does not include recommendations for their operational use nor does it imply that uses discussed here are registered. All uses of pesticides must be registered by appropriate State and Federal Agencies before they can be recommended.

MATERIALS AND METHODS

Ten-gallon (38-liter) and three-gallon (11-liter) pressure tanks (similar to carbonated drink fountain tanks) were fitted with two pressure hoses. One hose was connected to a nitrogen gas cylinder with a pressure regulator, the other to a spray chamber. The spray chamber consisted of a Fiberglas® sink and a clear Plexiglas® lid (fig. 1). A 1/2-inch (1.3-cm) pipe was inserted into the chamber and fitted with a pipe "T" to hold the nozzle assembly inside the chamber. A pressure gage and spray valve were fitted onto the pipe outside the chamber (fig. 2).

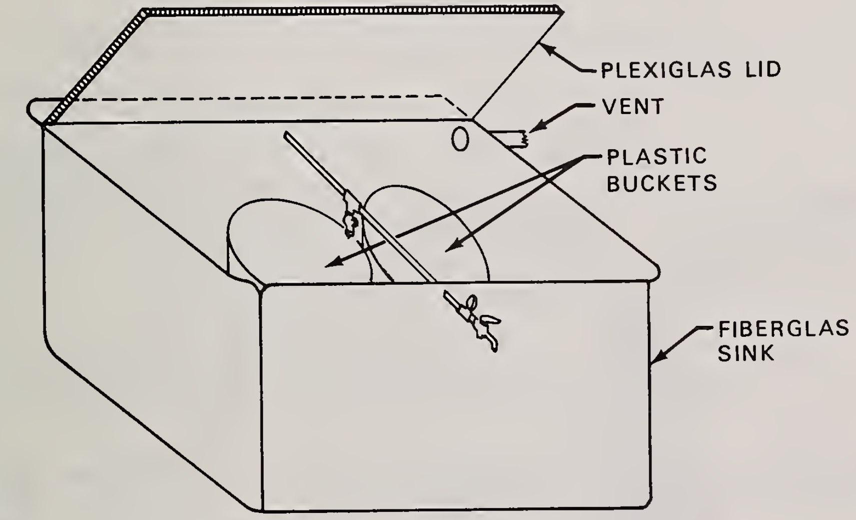

Figure 1.--Spray chamber.

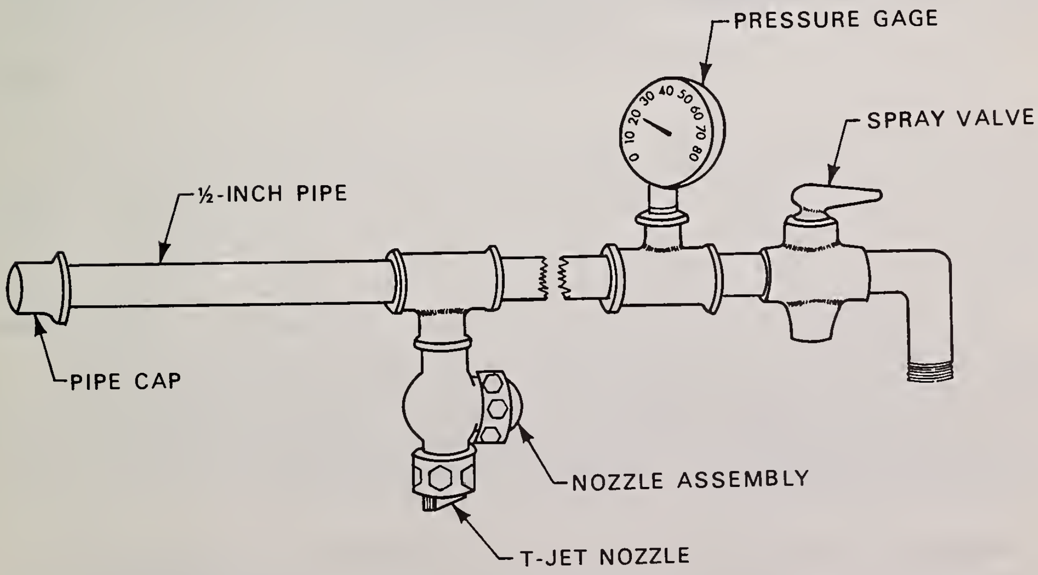

Figure 2.--Spray assembly.

During the tests, the chamber was kept under partial negative pressure by fitting a 1-inch (2.54-cm) Tygon® tube onto the chamber and onto a trap with a spun glass filter (fig. 3). An additional tube vented the trap outdoors and was fitted with an air pressure ejector to draw air from the spray chamber through the trap. It also kept spray mist and odors outside the room. The ejector had no moving parts that could cause sparks from friction.

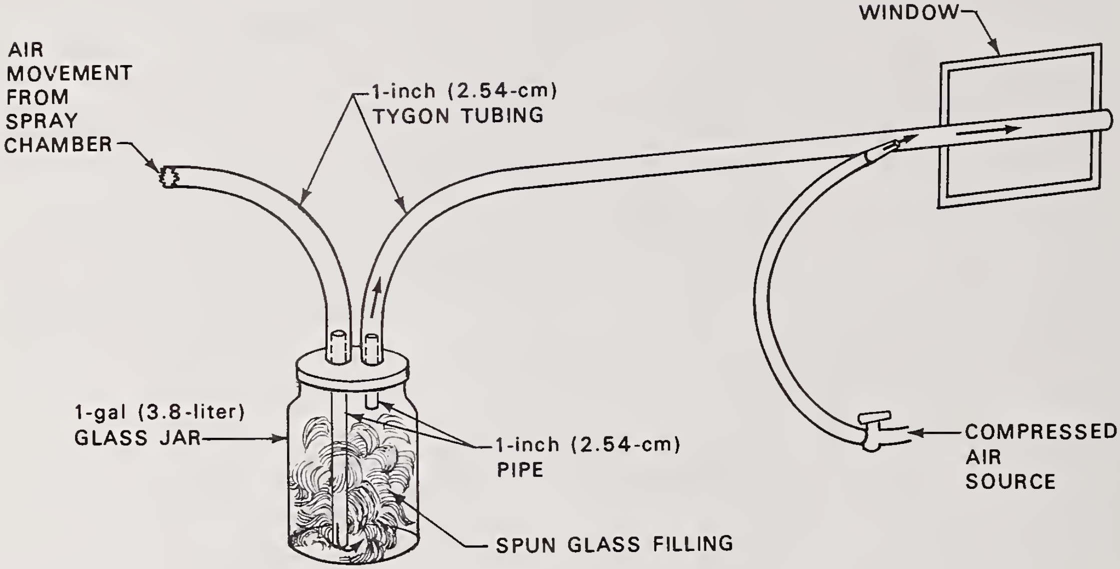
WINDOW
AIR MOVEMENT FROM SPRAY CHAMBER
1-inch (2.54-cm) TYGON TUBING
1-gal (3.8-liter) GLASS JAR
1-inch (2.54-cm) PIPE
COMPRESSED AIR SOURCE
SPUN GLASS FILLING

Figure 3.--Air vent system.

The formulation was mixed to the desired concentration, placed in the tank, and pressurized with nitrogen gas. Two plastic buckets were placed on the floor of the spray chamber, the spray valve was turned on, and the pesticide was sprayed through the system. An operator adjusted the pressure with a regulator on the nitrogen tank to compensate for friction in the nozzle supply system. Tank pressure was frequently 10-20 psi (51.71-103.4 cm Hg) higher than nozzle pressure.

When the pressure was established, the formulation was sprayed into plastic buckets for three 1-minute periods and then measured into a graduated cylinder. The three collections were averaged to estimate gallons per minute (ml/min) delivered through the nozzle.

The pesticides were tested at the following concentrations of active ingredient (ai), nozzle sizes, temperatures, and pressures:

Pesticide concentrations

Dimilin (TH6040)	1, 2, 4 ounces ai/gal (0.007, 0.015, 0.029 kg/liter) in water
Dylox 1.5	1.5 pounds ai/gal (0.180 kg/liter) of carrier as supplied by manufacturer
Orthene 75S	1/2, 1, 2 pounds ai/gal (0.059, 0.119, 0.238 kg/liter) in water
Sevin 4-oil	2, 3, 3.6 pounds ai/gal (0.238, 0.357, 0.428 kg/liter) in diesel fuel
Water, for comparison	

Nozzle sizes	800067, 8002, 8010
Temperatures	30, 40, 50, 60 °F (-1.1, 4.4, 10, 15.5 °C)--constant pressure of 40 psi (206.9 cm Hg)
Pressures	20, 30, 40, 50, 60 psi (103.4, 155.1, 206.9, 258.6, 310.3 cm Hg)--constant temperature of 55 °F (12.77 °C)

Low temperatures were obtained by placing the 3-gallon (11-liter) tank in an ice-rock salt bath. Other temperatures were maintained when the large tank was placed in a controlled warm water bath.

Viscosity was measured with a Brookfield® Viscometer Model VI and is expressed as centipoises (cps). Density was measured with volumetric flasks and a Mettler® balance.

Observations were also made on general physical characteristics. The results are summarized in the following pages.

Dimilin (TH6040)

Generally, Dimilin performed well in the spray system. It mixed well when first mixed as a slurry and then diluted (procedure recommended by Thompson-Hayward Chemical Co.). The particle size appeared uniform, and it was free of large foreign particles so filter screens did not plug up. The mixture had no objectional odor, sprayed well at the various temperatures, and did not freeze at 30 °F (-1.1 °C). At lower temperatures, however, it did freeze on the sides of the tank.

At the three concentrations, the flow rates of the different nozzles were virtually identical for temperature and pressure variations (figs. 4 and 5). This will simplify field operations if altering the concentraton of spray from one plot to another is necessary, because the spray system will not need to be changed.

In the field, Dimilin did not need to be mixed into a slurry before final dilution if:

1. The mixing tank was equipped with strong agitators. Ideally, this would be a recirculating pump plus two or three power-driven triblade paddles.

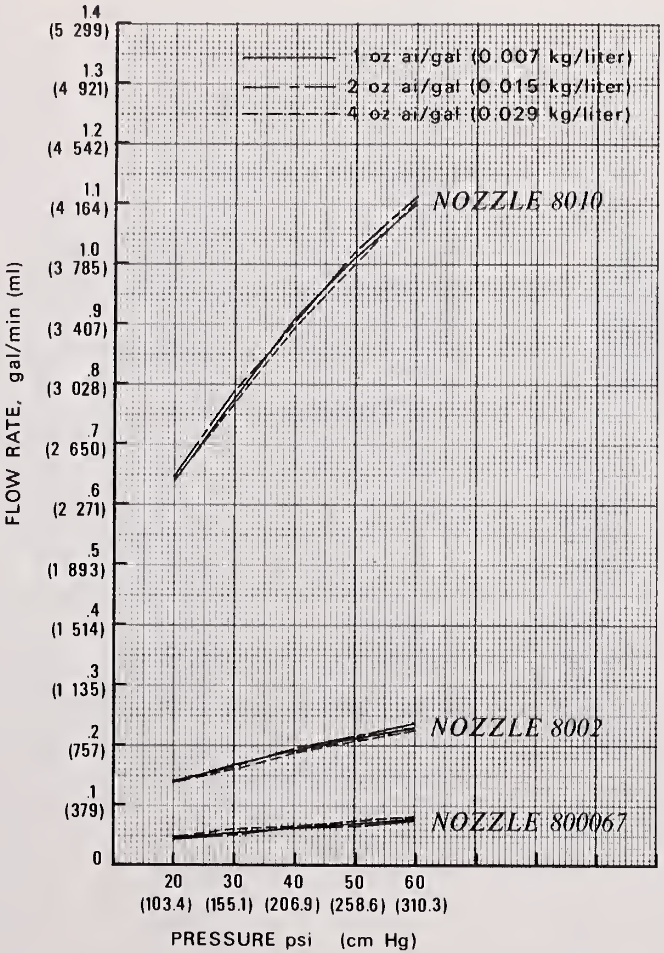

Figure 4.--Flow rates of Dimilin (TH6040) at various pressures.

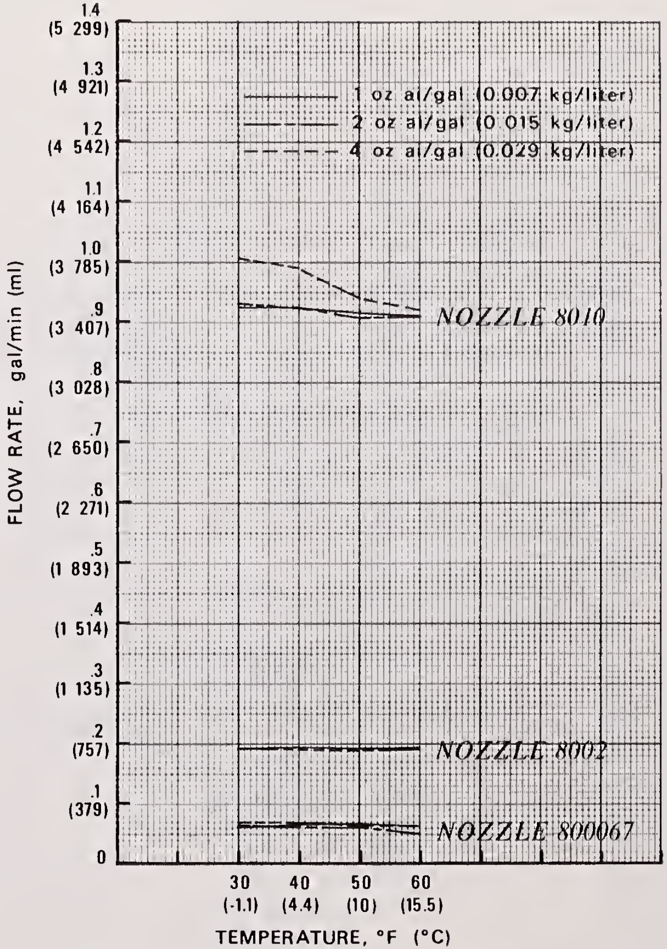

Figure 5.--Flow rates of Dimilin (TH6040) at various temperatures.

The paddle agitator may be sufficient if the material is added slowly. A strong recirculating pump also worked for up to approximately 8 ounces ai per gallon (0.59 kg/liter) of water.

2. The material on the liquid surface is mixed in by hand. As a safety precaution, all other agitators (especially paddles) should be stopped before the mixture is stirred by hand.

Dimilin foamed when agitated. This provided a surface layer that collected a portion of the powder and prevented it from going into solution. Some of this powder formed clumps that floated on top of the foam, but the clumps were dissolved when the foam was manually stirred into the liquid.

Settling was the most objectionable characteristic exhibited by Dimilin. Table 1 shows the amount of material settled out over a 12-day period. Most of this settling occurred within the first 24 hours. The settled material compacted with time and became extremely cohesive and difficult to resuspend. Resuspension required scraping or stirring of the material at the bottom of the tank to loosen the Dimilin and then agitating the mixture. Agitation of the solution with the pump or paddles left settled material in the corners of the tank.

Table 1--*Settling measurements of Dimilin (TH6040) in water (250-ml samples)*

Concentration	Settling time			
	24 hours	48 hours	6 days	12 days
	Milliliters			
4 oz/gal (0.029 7 kg/liter)	50	46	42	43
2 oz/gal (0.014 8 kg/liter)	22	17	18	20
1 oz/gal (0.007 4 kg/liter)	10	11	12	12

In practice, the formulation should be mixed immediately before spraying to minimize settling problems. If a large amount is mixed and cannot be sprayed immediately, we recommend that the solution be in constant agitation until it can be loaded into the spray equipment and sprayed.

If Dimilin is to be used in the aircraft spray system again the following morning, the system should be flushed with water immediately after spraying to avoid plugging of the lines from settling of material.

Density and viscosity measurements of Dimilin (TH6040) are as follows:

Density

4 oz/gal (0.029 7 kg/liter) = 8.65 lb/gal (1.038 g/cm^3)
2 oz/gal (0.014 8 kg/liter) = 8.43 lb/gal (1.011 g/cu^3)
1 oz/gal (0.007 4 kg/liter) = 8.19 lb/gal (0.982 1 g/cu^3)

Viscosity @ 20 °C

4 oz/gal (0.029 7 kg/liter) = 7 cps
2 oz/gal (0.014 8 kg/liter) = 6 cps
1 oz/gal (0.007 4 kg/liter) = 5.5 cps

Dylox 1.5

Dylox 1.5 was tested as supplied by the manufacturer since application plans did not call for further dilutions (figs. 6 and 7). It handled well under most conditions. The exception was at 30 °F (-1.1 °C) with the 800067 nozzle and 100-mesh screens which continually plugged. The material causing this was not saved. It was presumed to be congealed Dylox or carrier. The plugging was not evident with other nozzles or temperatures and was not considered a severe problem since neither the 30 °F (-1.1 °C) temperature nor the 800067 nozzle is used often in the field.

We had some difficulty in obtaining pressures of 40 psi (206.9 cm Hg) and higher, but we thought this was a problem arising from the construction of the system combined with the viscosity of Dylox (see "Limitations of Design").

Settling, density, and viscosity of Dylox 1.5 (1.5 lb ai/gal or 0.18 kg ai/cu^3) were as follows:

Settling (250 ml sample)

8 ml clear fluid on top
30 ml paste on bottom
Remainder, uniform color (white) and consistency

Density

9 360 g/cu^3 or 7.803 lb/gal

Viscosity

121 cps at 20 °C

The pastelike material that settles out was easily stirred back into suspension, as was the clear fluid that rose to the top.

Earlier reports (personal communication, Markin, Orchard, and Neisess, Forestry Sciences Laboratory, Corvallis, Oregon, 1975) indicated that before 1974 formulations of Dylox "clabbered" with small additions of water. In 1974, Chemagro began adding lethicin to its Dylox 1.5 formulation to alleviate

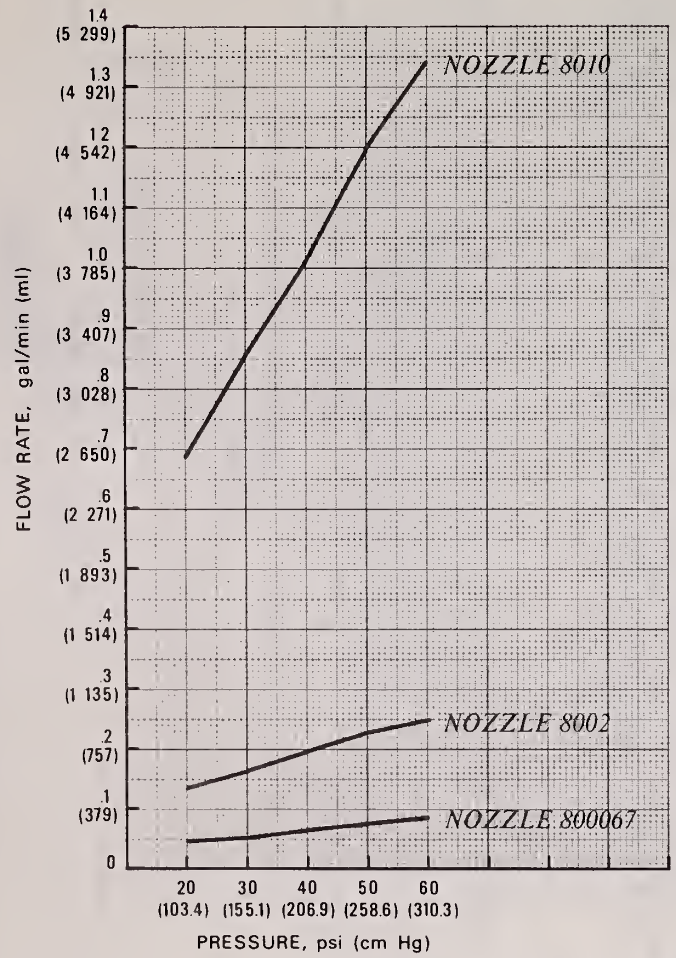

Figure 6.-- Flow rates of Dylox 1.5 at various pressures.

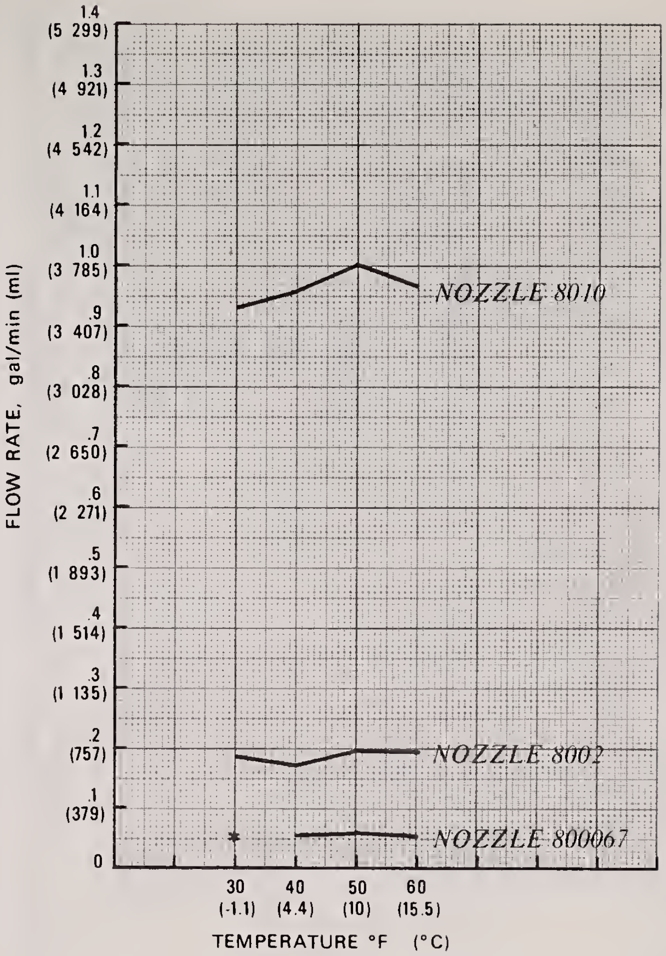

*Figure 7.--Flow rates of Dylox 1.5 at various temperatures. *Nozzle plugged.*

this problem. To determine if the problem still existed, we tested various water-Dylox mixtures with an 8002 nozzle at 40 psi (206.9 cm Hg). Table 2 shows a small change in flow rate at 4 percent water content and a large change at 6 percent (percentage by volume).

Table 2--*Change in flow rate of Dylox 1.5 caused by addition of water*

Percent of water in Dylox 1.5	Change in flow rate at 40 psi (206.9 cm Hg) and 55 °F (12.8 °C)
	Percent
1	3.38
2	5.46
4	7.85
6	11.11
8	12.87
10	14.23

Table 2 indicates that water-Dylox mixtures can be a problem in spray application. We found no indication of a "clabbering" reaction, however.

Pressure changes appeared to have a uniform effect on the flow rates. Figure 7 shows some not-so-regular flow rates. For example, the flow rate shown at 50 °F (10 °C) for the 8010 nozzle is 1.002 gal/min (3 793 ml/min), the mean flow rate for the 3 test minutes. The standard error is 43 ml, a variation of 1.13 percent in the measurements, which is probably not excessive.

Orthene

Orthene handled well in the spray system (figs. 8 and 9). The changes in flow rates were reasonably uniform during pressure and temperature variation. Orthene dissolved easily in water and was readily flushed from the system, unless it had a large depression or cul-de-sac where deposition could occur. Some material settled and compacted when allowed to stand overnight (table 3). This material was moderately difficult to resuspend.

Table 3--*Settling measurements of Orthene 75S (250-ml samples)*

Concentration	Settling time			
	24 hours	48 hours	6 days	12 days
	Milliliters			
1/2 lb ai/gal (0.06 kg/liter)	8	8	8	8
1 lb ai/gal (0.119 kg/liter)	13	12	13	13
2 lb ai/gal (0.238 kg/liter)	30	28	26	26

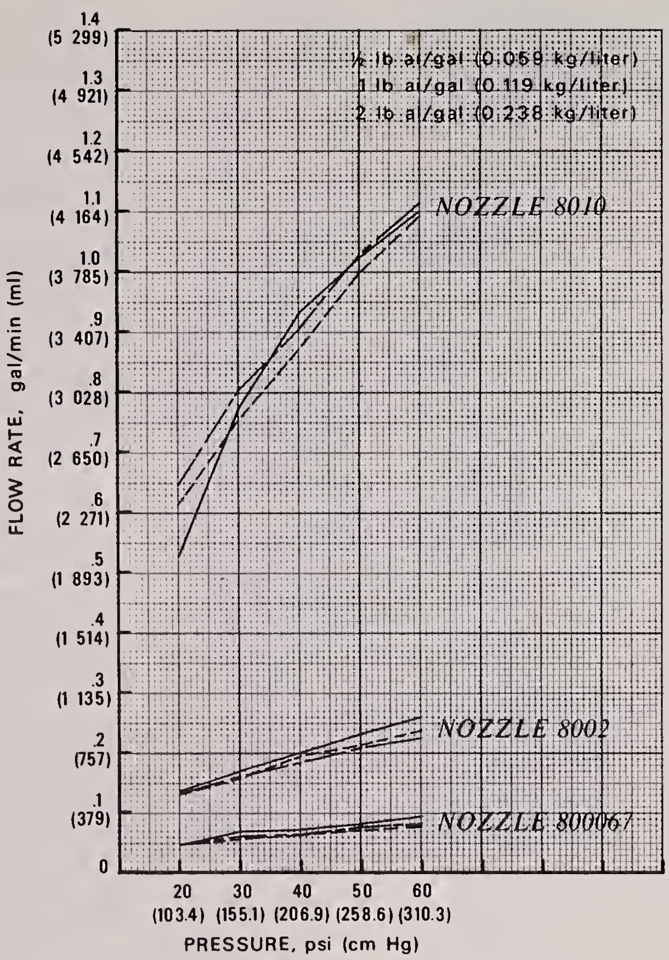

Figure 8.--Flow rates of Orthene 75S at various pressures.

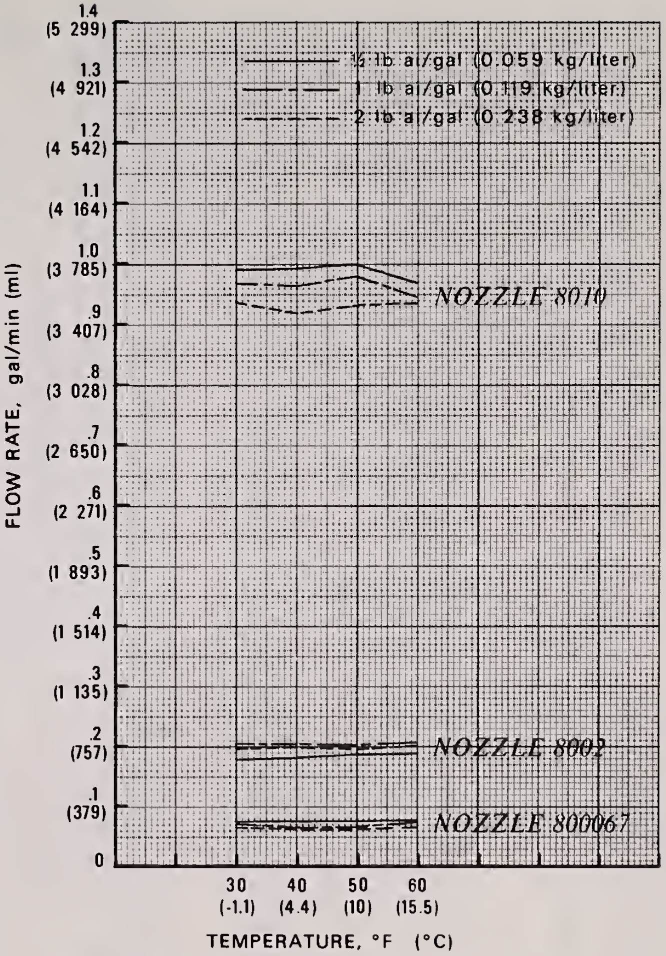

Figure 9.--Flow rates of Orthene 75S at various temperatures.

When resuspension began, the material broke off the floor of the container in irregularly shaped lumps, which could cause plugging under field conditions, but then suspended quickly. The more concentrated the formulation, the more difficult the resuspension becomes. If the resuspension was not uniform or complete, the lumps could cause severe problems in application.

Density and viscosity measurements of Orthene 75S were as follows:

Density

1/2 lb ai/gal (0.06 kg/liter) = 1.002 g/cu^3 or 8.35 lb/gal
1 lb ai/gal (0.119 kg/liter) = 1.017 g/cu^3 or 8.48 lb/gal
2 lb ai/gal (0.238 kg/liter) = 1.046 g/cu^3 or 8.72 lb/gal

Viscosity, at 20 °C

1/2 lb ai/gal (0.06 kg/liter) = 8 cps
1 lb ai/gal (0.119 kg/liter) = 8 cps
2 lb ai/gal (0.238 kg/liter) = 8 cps

Particulate foreign matter in the Orthene was a problem more serious than incomplete resuspension. Some plugging of screens and nozzles was observed. Orthene was mixed into filtered water in a cleaned container and filtered through a 100-mesh screen. Two kinds of particles were removed by the filter. One kind was dark and flakelike with diameters of 0.5 to 2 mm (0.0196-0.787 inches). The other was a plasticlike oily droplet, slightly gritty to the touch, approximately 1 mm (0.0392 inch) in diameter. The flake was heavier than water, the droplet lighter. The amount of residue was 0.27 g per 454 g of Orthene 75S (not 0.27 g per 454 g ai). The manufacturer indicates this problem has been corrected.

Sevin 4-Oil

When mixed with diesel (1:1), the Seven 4-oil performed fairly well in the spray system under various pressures and temperatures (figs. 10 and 11). The exception was at 40 °F (4.4 °C) with nozzle 8010. Since the other points are on a straight line, this discrepancy might have been caused by operator error.

At a dilution of 3:1 (3 parts Sevin:1 part diesel), the spray behavior became irregular. At 30 °F (-1.1 °C) (800067 nozzle), the nozzle plugged and the angle formed by the spray fan would not exceed 50° (80° is considered a full spray fan). The spray fan did not approach 80° until 60 °F (15.5 °C) was reached. When the 8010 nozzle was used, the tank pressure had to be increased to almost 80 psi (413.7 cm Hg) to obtain 40 psi (206.9 cm Hg) at the nozzle (see "Limitations of Design").

We tested pressure variation at 55 °F (12.8 °C) (800067 nozzle). The spray would not fan out properly (80°angle) until nozzle pressure was 50 psi (258.6 cm Hg) or above. When the 8010 nozzle was used, regulator pressures exceeded 80 psi (413.7 cm Hg) to achieve 50 psi (258.6 cm Hg) at the nozzle. We could not achieve 60 psi (310.3 cm Hg) nozzle pressure with the 8010 nozzle and three parts Sevin to one part diesel (see "Limitations of Design").

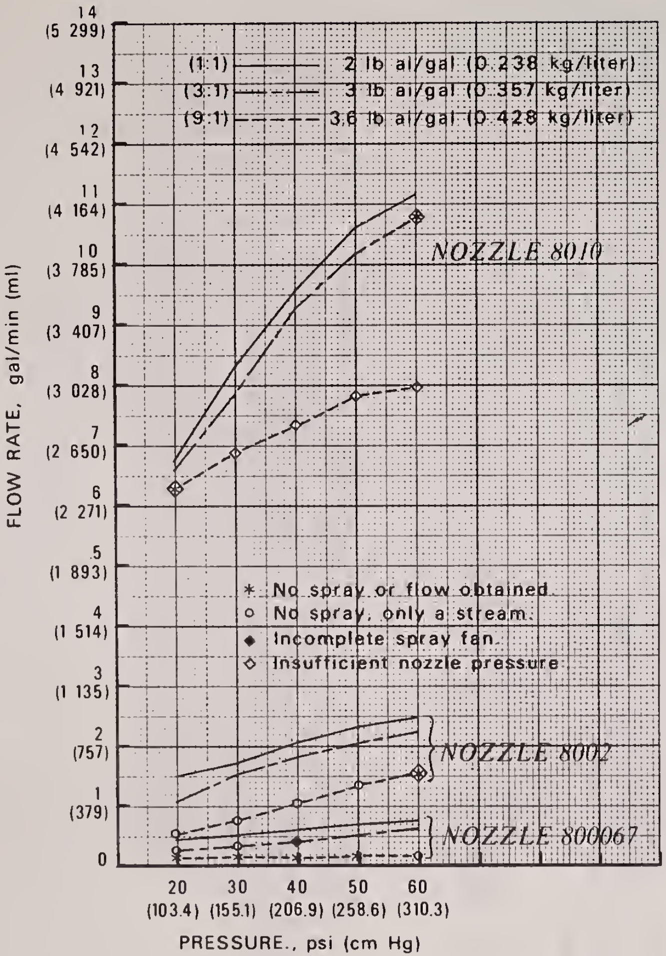

Figure 10.--Flow rates of Sevin 4-oil at various pressures.

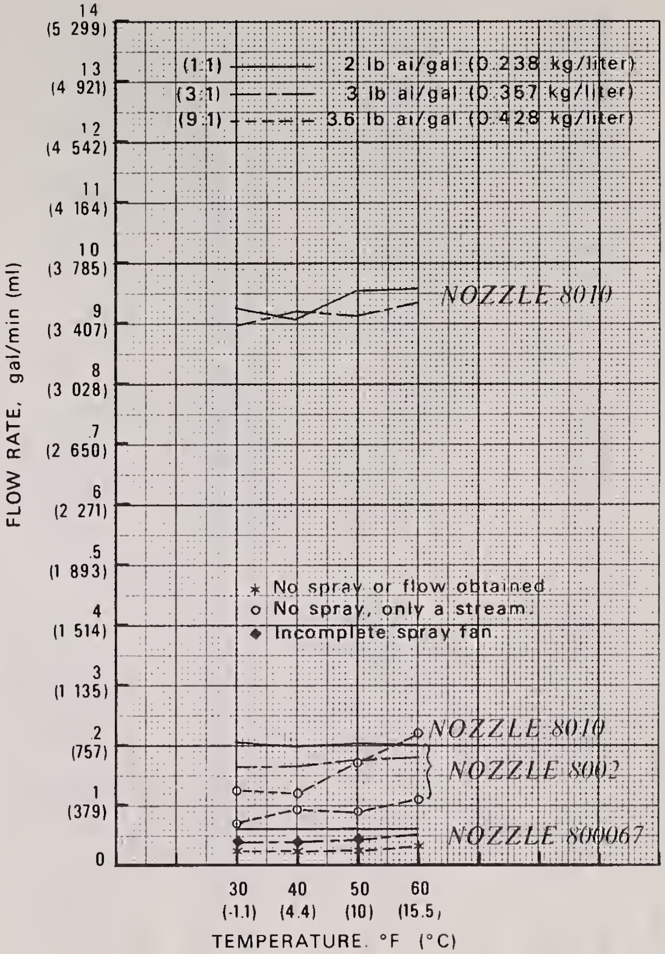

Figure 11.--Flow rates of Sevin 4-oil at various temperatures.

When nine parts of Sevin 4-oil was mixed with one part diesel (9.1), the formulation would not form a spray fan. The mixture left the nozzle as a stream of fluid, if at all (see "Limitations of Design").

Sevin 4-oil was not tested full strength. Settling, density and viscosity of 250-ml samples of Sevin 4-oil, as shipped (4 lb/gal or 0.476 kg/liter) were as follows:

Settling, 24 hours

2 lb/gal (0.238 kg/liter) = 5 ml clear fluid on top, 26 ml paste on bottom
3 lb/gal (0.357 kg/liter) = 4 ml clear on top, 17 ml paste on bottom
3.6 lb/gal (0.428 kg/liter) = 2 ml clear on top, no settled material

Density (mixed with fuel oil)

2 lb/gal (0.238 kg/liter) = 0.887 g/cu^3 or 7.395 lb/gal
3 lb/gal (0.357 kg/liter) = 1.01 g/cu^3 or 8.42 lb/gal
3.6 lb/gal (0.428 kg/liter) = 1.157 g/cu^3 or 9.645 9 lb/gal

Viscosity, at 20 °C

2 lb/gal (0.238 kg/liter) = 8.4 cps
3 lb/gal (0.357 kg/liter) = 44.5 cps
3.6 lb/gal (0.428 kg/liter) = 174 cps

No thick gummy precipitate settled out over a short period. The suspension appeared more dense toward the bottom. This suspended material did not exhibit more cohesive or adhesive properties, and it was easily stirred to a more uniform suspension. A small amount of clear fluid separated out at the top.

When allowed to stand for several hours, both mixtures with diesel (3:1 and 1:1) had a thick gummy paste, which was difficult to resuspend, at the bottom of the containers. The 9:1 dilution had no apparent settling problems.

This information indicated that, for other than immediate use, diesel fuel was incompatible as a carrier for Sevin 4-oil.

Water

The flow rates for water are presented for comparison (figs. 12 and 13). Figure 13 shows, partially, the effect of temperature on water density. The effect of temperature on flow rate was greatest at 40 °F (4.4 °C), but the differences may be masked by the temperature change of the water between output and measurement.

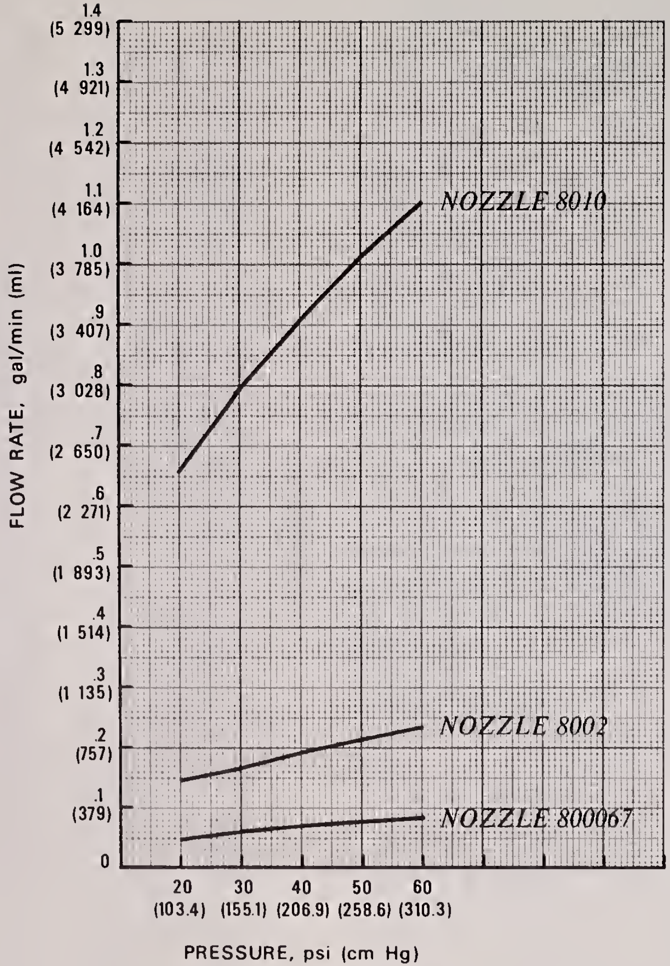

Figure 12.--Flow rates of water at various pressures.

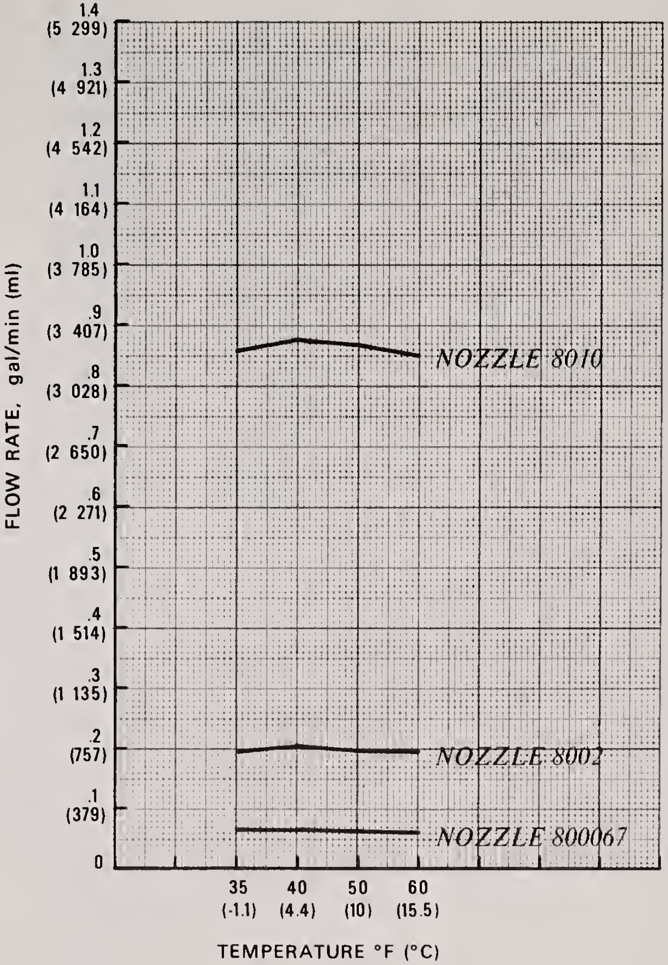

Figure 13.--Flow rates of water at various temperatures.

LIMITATIONS OF DESIGN

Several factors may have affected the results presented in this report. In addition, several test conditions should be altered in future tests.

First, we believe the diameter of the pipes and fittings from the pressure tank to the chamber were too small and caused difficulty with flow of the more viscous materials (Dylox 1.5 and Sevin 4-oil). This condition was shown by the large pressure drop from the tank to the nozzle, which may also have affected spray fan formation.

Second, a more appropriate way to measure flow rate would probably be to spray the material for 3-5 minutes, turning the spray on at the beginning and off at the end. This would eliminate some operator errors, such as reaction time, and would provide a more accurate estimate of flow rate. This would be especially important with the 8010 nozzles, since the larger orifice simply magnifies the error. This would, however, require larger volumes of formulations, chambers, and tanks, which would make the low temperature tests more difficult.

Third, there is some statistical validity for running these tests in a completely random order rather than sequentially. This was deemed impractical because of physical limitations, such as storage of all concentrations, temperature regulation of the chemical, frequency of cleaning test equipment, and additional time these precautions would require.

The system was designed to operate under pressure to eliminate or prevent, as much as possible, effects of other factors, such as mechanical friction and moving parts. Many aircraft spray systems use a centrifugal pump. The shearing action of a centrifugal pump may cause temperature increases of as much as 70 °F (37.2 °C), from 50 °F (11.7 °C) to 120 °F (48.9 °C) during application of a 50-gallon (189-liter) load (personal communication, J. Henderson, USDA/APHIS, Aircraft Operations, Hyattsville, Md., 1976). Similar temperature increases were also observed by Orchard, Forestry Sciences Laboratory, Corvallis, Oregon (personal communication, 1976). This was not known at the time of the test and would have greatly extended the range of the tests. This phenomenon should be investigated further in the laboratory and under field conditions, since it has the potential of altering the reliability, effectiveness, and properties of a given pesticide.

SUMMARY

This report has shown how pressure and temperature and concentration variables affect the flow rates of Dimilin, Dylox 1.5, Orthene 75S, and Sevin 4-oil. Some of their physical characteristics have been noted. Unfavorable results were due to settling and viscosity, but the limits of the facilities used in developing and testing the chemicals are recognized as having some effect.

We hope that these figures will be useful to other applicators and that they will encourage companies and research organizations to establish flow rates for other systems and chemical concentrations.

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife -- if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

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